GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station

PROJECT INITIATION

REVISED

Date: Jan. 2, 1975

oject Title: The Potential of Coastal Georgia as a Site for a Solar Energy Research and Development Laboratory

oject No.: A-1702

oject Director: N. B. Poulos

onsor: Coastal Area Planning and Development Commission

fective 12/10/74 Estimated to run until 9/10/75*

ype Agreement: Subcontr. under EDA Grant Amount: $ 30,000

eports Required: Monthly Activity Reports, Final Report

onsor Contact Person (s):

Mr. Vernon Martin
Executive Director
Coastal Area Planning & Development Commission
P.O. Box 1316
Brunswick, Georgia 31520

*Including submission of Final Report

ssigned to HIGH TEMPERATURE MATERIALS DIVISION Division

OPIES TO:

- ☐ Project Director
- ☐ Director
- ☐ Assistant Director
- ☐ GTRI
- ☐ Division Chief (s)
- ☐ Branch Heads
- ☐ Service Groups
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GEORGIA INSTITUTE OF TECHNOLOGY
ENGINEERING EXPERIMENT STATION
PROJECT TERMINATION

Date: December 16, 1975

Project Title: The Potential of Coastal Georgia as a Site for a Solar Energy Research and Development Laboratory

Project No: A-1702

Project Director: N. E. Poulos

Sponsor: Coastal Area Planning & Development Commission

Effective Termination Date: September 3, 1975

Clearance of Accounting Charges: by Nov. 30, 1975

Grant/Contract Closeout Actions Remaining: None

Assigned to: Applied Sciences laboratory

COPIES TO:

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ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

January 9, 1975

Mr. Tom Hilton
Coastal Area Planning &
Development Commission
P. O. Box 1316
Brunswick, Georgia 31520

Subject: Activity Report No. 1, Research Project A-1702, "The Potential of Coastal Georgia as a Site for a Solar Energy Research and Development Laboratory."

Dear Mr. Hilton:

Typical climatological data was obtained for the preliminary characterization of the insolation (solar energy received) and climate of the coastal Georgia area. This type of information is necessary so that the suitability of various types of solar energy research studies as well as the feasibility of industrial, agricultural, and domestic applications can be determined. The total solar radiation only is usually measured at weather stations. However, both the direct and diffuse components of the solar radiation must be known to make adequate engineering assessments of many applications. These components will be determined by an analytical procedure based on the best insolation data for coastal Georgia. A visit is planned early in the program to Glynco Naval Air Station to obtain as much insolation and climate data as is available for use in the program.

Work was also initiated in formulating the approach to be used in determining comfort heating and cooling requirements and the preliminary phase of solar energy applications in agriculture was started.

Coincidentally, the initiation of the present program and a visit to the Georgia Tech campus by the Transportable Solar Laboratory occurred simultaneously. This laboratory is a joint National Science Foundation-Honeywell program whose purpose is to obtain solar energy heating and cooling data for various locations in the United States. Its visit provided the opportunity for personnel of the program to observe at first hand current state of the art experimental equipment in operation. The solar collectors are of the flat plate type with two transparent covers and absorbers with selective coatings. Thermal energy storage is accomplished with two water tanks. The heating system is relatively simple and uses a gas fired boiler for supplemental heat as required. Two different types of air-conditioning systems may be used. One is a Rankine cycle unit using an organic working fluid, and the other is a lithium bromide absorption unit. It is anticipated that these types of components will find application in the current program.

Although not directly related to the present program, there are ongoing research efforts concerning high temperature solar furnaces and solar electrical power generation being conducted by other members of the High Temperature Materials Division staff. This will provide an invaluable source of information for certain aspects of the present program involving high temperature solar energy.

Respectfully submitted,

N. E. Poulos
Project Director

jw

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

February 10, 1975

Mr. Tom Hilton
Community and Industrial Developer
Coastal Area Planning and
Development Commission
P. O. Box 1316
Brunswick, Georgia 31520

Subject: Activity Report No. 2, Research Project A-1702, "The Potential of Coastal Georgia as a Site for a Solar Energy Research and Development Laboratory"

Dear Mr. Hilton:

The current status of this project is presented in the following paragraphs. The tasks and descriptors used correspond to the outline and milestone forecast sent to you in January.

I. INSOLATION AND CLIMATE

A. Insolation

1. Direct and Diffuse Components. The average daily direct insolation by month for the coastal Georgia region was bracketed using information published by the United States Department of Commerce. Data for Charleston, South Carolina and Gainesville, Florida were used. These are the nearest coastal cities to Brunswick which reported insolation in the Department of Commerce reports. The values reported were sufficiently close to each other so that no attempt was made to develop an interpolation procedure.

The direct component of insolation was calculated using an equation recently developed by others in research work related to electrical power generation by solar energy. This equation, although approximate, is believed to be sufficiently accurate for the present project during the months of high total insolation. The diffuse component is the difference between the total insolation and the direct component.

2. Cloud Cover. The mean sky cover, mean monthly hours of sunshine, and mean monthly percent of possible sunshine have been obtained for Jacksonville, Florida and Savannah, Georgia; the nearest reporting stations. As with the insolation, the values are such that reliable estimates can be made for coastal Georgia.

B. Climate

1. Temperature and Relative Humidity. Although some data was obtained for Brunswick on average monthly temperatures and heating degree days, this information was also obtained as monthly averages for Jacksonville and Savannah as well. In addition, monthly average ranges of relative humidity were obtained for these two cities. Although monthly averages for several years have not beem compiled for cooling degree days, yearly records are available and can be averaged if required.

C. Evaluation and Comparison of Coastal Georgia With Other Regions of the Continental United States

This phase of Task I has just begun with data assimilation. Some preliminary comparisons have been made.

II. DOMESTIC APPLICATIONS

None of the phases of this task have been completed. Calculational procedures are presently being developed for this task. The final calculations under this task will be based on selected buildings at GLYNCO.

A preliminary selection has been made and a request for specific information will be sent to CAPDC soon.

Respectfully submitted,

C. W. Gorton, Professor
School of Chemical Engineering

Approved:

N. E. Poulos
Project Director

jw

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

March 11, 1975

Mr. Tom Hilton
Community and Industrial Developer
Coastal Area Planning and
Development Commission
P. O. Box 1316
Brunswick, Georgia 31520

Subject: Activity Report No. 3, Research Project A-1702, "The Potential of Coastal Georgia as a Site for a Solar Energy Research and Development Laboratory"

Dear Mr. Hilton:

The current status of this project is presented in the following paragraphs. The tasks and descriptors used correspond to the outline and milestone forecast sent to you in January.

I. INSOLATION AND CLIMATE

This task has been completed.

II. DOMESTIC APPLICATIONS

None of the phases of this task have been completed, although all of them have been considered to some extent. Each of these phases will be discussed in turn.

A. Comfort Heating and Cooling

The comfort heating system selected for study is one using water as both a heat transfer fluid as well as a storage medium. A fixed angle flat plate collector with glass cover plates will be used as a basis for calculations. It will be oriented at an angle suitable for winter time operation. The collection efficiency used will vary with both environmental temperature and insolation. The expression to be used for this variation has been determined. Storage calculations will be limited to determining the amount of water required. The primary output of this phase of Task II will be expressed as the collector area required on some unit basis. Tentatively, the unit basis selected is square feet of collector required per therm of energy delivered. A therm is one million Btu's (British thermal units).

The comfort cooling systems to be used for calculations will include both heat driven (absorption) as well as mechanical. Both ammonia-water and lithium bromide-water absorption systems are being considered. The mechanical system to be studied will make use of a turbine driven mechanical refrigeration device. The output of this phase of Task II will also be presented on a unit basis, probably as collector area per ton of refrigeration. This phase of the study will also be based on a fixed angle collector, but at such an angle as desirable for summer time operation. The yearly zenith angle variation of the sun in the Brunswick area to be used in this study has been determined.

B. Hot Water and Steam

The collector area requirements as well as storage requirements will be based on the same type of flat plate collector referred to in the discussion on comfort heating. The results will probably be reported as collector area per gallon of water per day.

The steam generation calculations will be based on a different type of device rather than a flat plate collector. Although it is possible to generate steam at elevated temperature (greater than 212° F) using a flat plate collector with a selective coating, practical devices at present seem limited to some form of optical concentration by multiple collection mirrors and/or lenses or curved mirrors. This phase of the study will be based on collection efficiencies obtained from current research programs. An output such as total collection area per one thousand pounds of steam will be used.

C. Electrical Power

This phase of the study will consider both dynamic electrical power generation (turbine-generator) as well as solar cells (photovoltaic devices). Dynamic electric power generation will be based on current studies, scaled to some extent for size effect, if deemed necessary.

III. AGRICULTURAL APPLICATIONS

This task has been initiated with calculations to investigate the sensitivity of soil temperature to various parameters such as wind velocity and earth albedo.

Essentially all of the input data has been compiled and all calculational procedures have been formulated under Task II.

Respectfully submitted,

C. W. Gorton, Professor
School of Chemical Engineering

Approved:

N. E. Poulos
Project Director

jw

A-1702

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

April 15, 1975

Mr. Tom Hilton
Community and Industrial Developer
Coastal Area Planning & Development
  Commission
P. O. Box 1316
Brunswick, Georgia 31520

Subject: Activity Report No. 4, Research Project A-1702, "The Potential of Coastal Georgia as a Site for a Solar Energy Research and Development Laboratory"

Dear Mr. Hilton:

The current effort on this project is discussed in the following paragraphs.

Preliminary calculations were made to determine flat plate collector sizes required for comfort heating, and for cooling with absorption refrigeration. Also, calculations were made on hot water heating. These results indicated that a more detailed analysis should be made concerning the use of the insolation data compiled under Task I. The available insolation data has been reported for a horizontal surface. The flat plate collectors to be evaluated in the present study are to be inclined at an angle. To interpret adequately the effect of this angle, calculations of the angular position of the sun as a function of time of day and day of the year were made for a horizontal surface for June 21 and December 21, 1975. The decision was made to base the energy received by a flat plate collector which is oriented so that the sun's rays are perpendicular to the surface of the collector when the sun is at its zenith, but the collector is assumed fixed at this position throughout the entire day. The calculations of the angle between the sun's rays and the perpendicular to the inclined collector as a function of the time of day for June 21 and December 21, 1975, have also been made.

The results referred to in the previous paragraph will be used in an approximate expression to determine the rate at which solar energy is received as a function of the time of day. This, with a suitable efficiency expression, will be used to determine the daily output of energy from the flat plate collectors.

Respectfully submitted,

C. W. Gorton, Professor
School of Chemical Engineering

Approved:

N. E. Poulos
Project Director

jw

A-1702

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

June 19, 1975

Mr. Tom Hilton
Community and Industrial Developer
Coastal Area Planning & Development
Commission
P. O. Box 1316
Brunswick, Georgia 31520

Subject: Activity Report No. 6, Research Project A-1702, "The Potential of Coastal Georgia as a Site for a Solar Energy Research and Development Laboratory"

Dear Mr. Hilton:

A simplified analysis to determine the effect of various parameters on soil temperature was finalized during this activity period. In addition, a preliminary study was initiated to determine possible solar energy usage in a combined fresh water-minerals beneficiation plant using sea water. Also initiated was a method to determine the solar energy requirements for the production of gum turpentine by steam distillation.

The color slides made from photographs taken by Mr. A. T. Sales on his visit to Glynco during the last activity period have been tentatively reviewed. The recordings made at the scene by Mr. Sales have been transcribed and correlated with the corresponding slide for detailed screening later in the program. This will be done before the anticipated visit during the summer by senior project personnel.

Respectfully submitted,

C. W. Gorton, Professor
School of Chemical Engineering

Approved:

N. E. Poulos
Project Director

jw

A-1702

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

August 13, 1975

Mr. Tom Hilton
Community and Industrial Developer
Coastal Area Planning & Development
Commission
P. O. Box 1316
Brunswick, Georgia 31520

Subject: Activity Report No. 8, Research Project A-1702, "The Potential of Coastal Georgia as a Site for a Solar Energy Research and Development Laboratory

Dear Mr. Hilton:

The writing of the final report was initiated during this activity period. The preliminary draft of the chapter on insolation and climate has been completed. Work is progressing on the chapter concerning applications as well as on the appendices. It is anticipated that the text of the final report will be of a general nature with the more technical aspects included as appendices.

The scope of the report will include all items mentioned in the proposed work section of the proposal.

Respectfully submitted,

C. W. Gorton, Professor
School of Chemical Engineering

Approved:

N. E. Poulos
Project Director

jw

A-1702

FINAL REPORT

Project A–1702

THE POTENTIAL OF COASTAL GEORGIA AS A SITE FOR A SOLAR ENERGY RESEARCH AND DEVELOPMENT LABORATORY

By

C. W. Gorton
A. T. Sales
N. E. Poulos

Prepared for

Coastal Area Planning and Development Commission
Brunswick, Georgia

September 1975

1975

Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia

FINAL REPORT

Project A-1702

THE POTENTIAL OF COASTAL GEORGIA AS A SITE FOR A SOLAR ENERGY RESEARCH AND DEVELOPMENT LABORATORY

By

C. W. Gorton
A. T. Sales
N. E. Poulos

September 1975

Prepared for

Coastal Area Planning and Development Commission
Brunswick, Georgia

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

FOREWORD

Under this program it was proposed that the various types of structure and facilities available at the Glynco Naval Air Station and the Fort Stewart-Hunter Complex including: family housing, barracks, mess halls, hospitals, warehouses, and other available facilties were to be surveyed so that typical structural units could be specified. These units were to be characterized in sufficient detail so that reliable estimates of heating and cooling requirements as well as hot water, steam, and electrical requirements could be made. Unique features which could be adapted to solar energy studies, such as, concrete aprons, runways, water towers or control towers were to be included. Of the three military bases only Glynco was used for the study. This selection was mutually agreed upon by the sponsor and Georgia Tech, and was based on the fact that only Glynco was to be decommissioned in the foreseeable future. However, the results of the studies based on the Glynco structures can be used generally for the Fort Stewart-Hunter Complex and other similar military facilities and structures, since the insolation and climate in the entire coastal Georgia region is essentially the same.

It is of interest to note that this program was well underway before the recent announcement by the Energy Research and Development Agency (ERDA) of its interest in establishing a Solar Energy Research Institute (SERI) for solar energy research and development. Since Glynco has been decommissioned, it is a viable site for the location of such an institute.

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I. OBJECTIVE

The objective of this study was to determine the potential of the coastal area of the state of Georgia as a site for solar energy research using existing military bases.

II. BACKGROUND

Developing both economical and renewable energy resources to supplement the dwindling supplies of gas and oil may become one of man's greatest challenges of the 20th century. There has been accelerated activity in research institutions and in various government agencies during the past few years in an attempt to assess the potential of various alternative energy resources. These activities have identified several areas where research tasks should be accelerated and/or major developmental programs initiated. Solar energy is one of these areas.

Solar radiation is man's largest natural renewable energy resource. It is so plentiful that daily solar energy arriving on less than one percent of land area of the United States has been estimated to provide more energy than the total energy requirements of the country for the remainder of the century. Although man has long recognized the potential of solar energy, it has been used only in a limited way. Water heaters, high temperature furnaces, space applications and to a lesser extent house heating are representative of the areas in which solar energy has been applied with some success. Although systems could be built now for heating and cooling houses and for generating electricity, the technologies have not been developed which would allow their wide spread economic use. Industrial uses have not been emphasized, but many large and small scale industrial processes may be accomplished using solar energy.

Of the proposed uses of solar energy, the heating and cooling of houses and buildings are the most developed and will probably be the first to realize significant use. The thermal generation of electricity from solar energy is a more difficult problem and there are conflicting ideas about the best approach to the solution. One of the obstacles facing the development of systems for the production of electrical power from solar energy is related to the large scale experimental effort necessary to develop the prototype units required to establish the economic potential of these systems. In addition to the costs associated with this development, there are problems of site location both from the standpoint of insolation (solar radiation received over a given area) and to a lesser extent the proximity to potential customers. Generally, attention has been focused on the sun bowl areas of Arizona, New Mexico, and California as illustrated in Figure 1. However, most of the south and southeastern parts of the United States receive sufficient sunshine to warrant serious consideration for experimental solar energy studies of all types. The ultimate success of solar energy could very well depend upon the development of systems which would function in various sections of the country rather than just the sun bowl areas of the Southwest.

A research and development solar energy facility should be located in a region of good insolation and should be versatile so that a variety of concepts could be tested, ranging from hot water heaters for single residences to a ten megawatt electrical power generating plant or a heating and cooling system for a building or building complex. The facility should also provide the capability for studying various industrial processes, such as: desalination, beneficiation of minerals from the ocean, and the production of aluminum oxide and aluminum from kaolin. Single residences as well as large buildings should be available for experimentation. About two-thirds of the state of Georgia, south of the fall line, receives

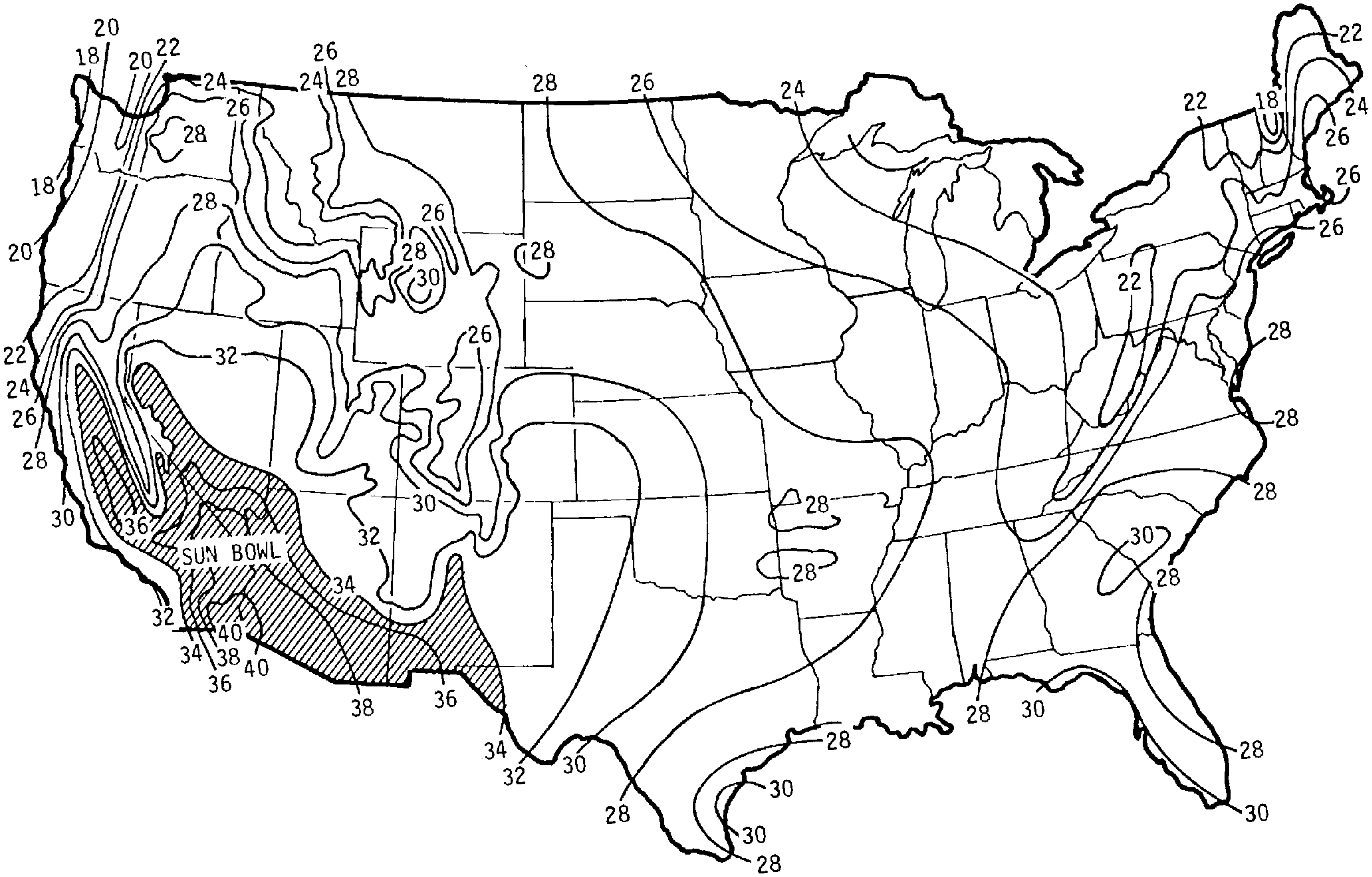

Figure 1. Insolation Distribution in the United States
(Hundreds of hours of sunshine per year).

abundant solar energy and should be seriously considered for the location of a solar energy developmental facility. The decommissioned Glynco Naval Air Base of Brunswick, Georgia, and shown in Figure 2, is an ideal site. The availability of Glynco precludes the necessity of acquiring the land or the construction of buildings. Also, innovative experiments could be performed without the restraint of building and zoning codes and other restrictions which apply to privately owned buildings and houses.

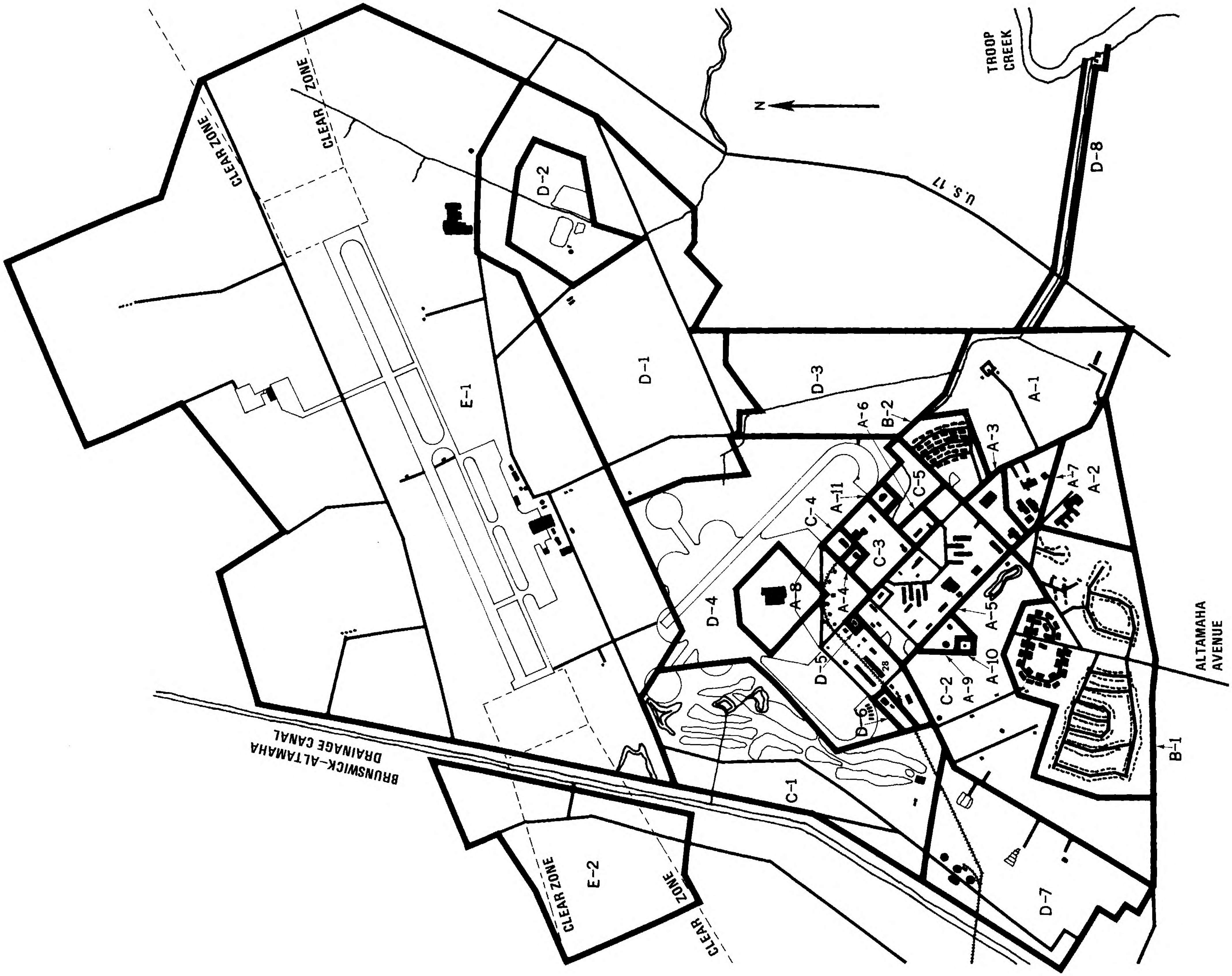

Figure 2. Map of Glynco Naval Air Station With Use Sections Indicated.

III. INTRODUCTION

The work reported herein was performed by personnel of the Solar Energy and Materials Technology Division (SEMTD), Engineering Experiment Station (EES), Georgia Institute of Technology, Atlanta, Georgia, under a subcontract with the Coastal Area Planning and Development Commission, Brunswick, Georgia. The Solar Energy and Materials Technology Division was responsible for an assessment of an available site located in the coastal area of Georgia for use as a solar energy research and development center; technical assessment of the insolation and climate of the region in conjunction with the available facilities; recommendation of various developmental programs suitable for immediate implementation; consideration of appropriate program planning; and coordination of the studies relative to their effect on civilian applications as well as the industrial and agricultural needs peculiar to the region.

Current solar energy effects are generally grouped as photovoltaic, photochemical, and thermal. Most of the past and current applications considered for solar energy effects, have been directed towards thermal usage. This was the case for this study; however, some applications related to photovoltaic and photochemical effects were considered.

There are two important aspects of solar thermal energy that must be considered in any application. The amount of energy and the temperature at which this energy can be made available for use. Quite clearly, the solar energy must be intercepted before it can be used. Also, the particular application will indicate the temperature requirement. For example, the sun may increase the temperature of a lake in summer to a temperature suitable for swimming, but special provisions will be necessary to provide water at a temperature suitable for domestic hot water use. In addition, the intermittent nature of solar energy from day to night and on cloudy days must be considered. The usual implication is that either storage be considered in some form or an alternate energy source be available as needed. As a matter of fact, solar energy can be used to perform the same thermal functions as other energy sources. However, the cost of such a venture will depend on the equipment required to collect the solar energy and to provide the temperature level required. The size of the collection equipment will depend on the insolation as well as the collection efficiency. These factors are directly relatable to the insolation and climate.

A. Insolation and Climate

The proposed study provided for a characterization of the specific solar environment using available information. Both direct and diffuse solar radiation were considered as well as the frequency of cloud cover as a function of the time of day and the day of the year. This information was estimated from existing data and/or prediction methods. The climate of the region was described based on the type of information normally used for designing space heating and air conditioning systems. The final phase of the study resulted in mathematical and extrapolated characterization of the solar energy received as well as the environment imposed by local weather conditions.

B. Types of Structures and Facilities

The various types of structures and facilities available on the decommissioned Glynco Naval Air Station were surveyed from available information (family housing, barracks, mess halls, hospitals, warehouses, and other available facilities) so that typical structural units could be specified. These units were characterized so that estimates of heating and cooling requirements as well as hot water, steam, and electrical requirements could be made. Also, central facilities for providing such services were surveyed. Typical units available for study were characterized. Portions of the study were based on information supplied by the Coastal Area Planning and Development Commission.

C. Recommended Research and Development Programs

Specific developmental and research programs were identified utilizing the existing structures and facilities. The effect of insolation and climate of the region in this selection procedure were identified. Preliminary engineering calculations were made as required to complete the study. Consideration was given to (1) hot water heating, (2) space heating, (3) air conditioning, (4) architecture, and (5) total energy systems. Identification of civilian and military applications was made. The use of solar energy in agricultural and industrial applications was considered. Both existing and potentially feasible industries which could utilize solar energy in the region were included. Information on existing and potential industries was supplied by the Coastal Area Planning and Development Commission. Electrical power generation was also considered. The results of the study were a ranking of developmental projects in proposed chronological order. A brief discussion presented general methods of implementation as well as comments concerning the applicability of the expected results to other sections of the country as well as the impact of the project upon the nation's energy usage.

D. Solar Energy Application Studies

Solar energy studies which could be undertaken in Coastal Georgia are presented with particular emphasis on those more uniquely suited to the area.

1. Evaporation

Evaporation refers to the vaporization of a liquid at temperatures less than its boiling point. In solar energy applications evaporation serves two primary functions, either separately or simultaneously, of providing fresh water from sea water or brackish water and in minerals beneficiation. Salt as well as many other compounds are available in sea water. A typical elemental composition of sea water is given in Table I. Complete evaporation of the associated water will, of course, give all of the elements listed. Various separation techniques would have to be used if specific compounds or elements are desired. Magnesium has long been produced economically from sea water. Although the Glynco facility itself does not lend itself directly for sea water evaporation studies, its proximity to the coast would permit nearby field sites to be easily monitored or, if desired, some of the available land area could be used for this purpose.

2. Solar Ponds

The use of solar ponds to provide low temperature process energy has been studied for some time. In using solar ponds surface evaporation is not desired as it suppresses the temperature level in the pond. One type of pond currently in the research stage is to use an open pond, but one in which the heated lower depths are made of higher density by purposely maintaining a high salt concentration near the bottom of the pond. This aids in

TABLE I

MAJOR ELEMENTS IN SEA WATER*

Element	Pounds per Million Gallons
Chlorine	162,904
Sodium	90,594
Magnesium	10,574
Sulfur	7,413
Calcium	3,571
Potassium	3,241

*Based on data in Reference 1.

maintaining the water surface at a lower temperature, thus, reduces loss at the surface associated with convection and evaporation. Another type of pond, in the development stage, is a covered pond with two plastic covers. The water itself is enclosed with one plastic cover. The outer cover is separated from the first by an air layer which serves to reduce energy losses. Either of these two types of ponds could easily be studied at Glynco.

3. Domestic Hot Water Heating

Hot water heaters usually use flat plate collectors. Typically, the collector is composed of two glass cover plates (plastic film may be used, but it usually does not perform as well as glass) with a blackened back surface through which the water flows. An efficiency based on the daily solar energy incident on the collector (both direct and diffuse) is about fifty percent (procedures are available in the literature for calculating the efficiency). The collectors are usually well insulated on the back side. Hot water heaters for domestic hot water should function well in the Glynco area.

4. Agricultural Drying

Agricultural drying using solar energy can be accomplished using flat plate collectors, although other types of solar collectors can also be used. In one approach the air passes directly through a flat plate collector similar to the type discussed under Domestic Hot Water Heating. This air can then be used directly for drying agricultural products such as wood, corn, soybeans, and peanuts either before storage or before processing.

In drying agricultural products temperature limitations are imposed by the material being dried. If the material attains too high a temperature, the product may be rendered worthless or suffer a substantial loss in value. A problem associated with drying in coastal areas is that the relative humidity is usually high. This may necessitate some type of moisture removal (as for example, by the use of silica gel which is regenerated with solar energy). The high relative humidity of the coastal Georgia area, although a problem, is not considered a disadvantage for solar energy drying experiments since studies conducted under this condition would provide a regional value related to population density rather than sparcely populated areas which have more favorable climate.

5. Comfort Heating

Comfort heating using solar energy is usually provided with flat plate collectors heating water or air. The flat plate collectors used are similar to those previously discussed under Domestic Hot Water Heating and

Agricultural Drying. Usually, electrical controls and electrical pumps or fans are used to move the heat transfer medium. Some work has been done on natural convection systems using air. No particular difficulty is expected if solar energy is used for comfort heating in the Glynco area. Some work has been done using heat pumps to provide comfort heating with the solar collector providing the energy source for use by the heat pump. This is also a potential candidate for study at Glynco, but does require considerable electrical power.

6. Comfort Cooling

There are three main types of devices to be considered in providing solar-power comfort cooling. These are mecahnical, absorption-desorption, and adsorption-desorption devices. The mechanical devices are the same as currently used. The difference being that mechanical input would be provided either by heat engines using solar energy or by electricity generated by solar energy (these will be discussed in a later section). Consequently, mechanical cooling will not be discussed further here. Absorption-desorption devices have been used for a long time and can be readily adapted to solar energy by using the solar energy as the energy source. The two most common ones are the ammonia-water and water-lithium-bromide system. The ammonia-water system suffers from two major disadvantages. Relatively high temperatures are needed for the regenerator for efficient operation and ammonia is toxic. The advantage of ammonia is that relatively low temperatures can be attained as, for example, for manufacturing ice. Adsorption-desorption devices operate by removing moisture from the air by means of a drying agent, such as silica gel, followed by a water spray which simultaneously cools and rehumidifies the air to comfort conditions. In this case the role of solar energy would be to supply the energy needed to regenerate the silica gel. In some hot, dry climates, only a spray of water or passing the air through damp material may be sufficient to provide some measure of comfort cooling.

7. Heat Engines

Solar energy may, of course, be used as the high temperature energy source for any type of heat engines. These may be conveniently discussed as vapor cycles and gas cycles. The idealized vapor cycle is referred to as a Rankine cycle. This cycle consists of a boiler and superheater, an engine or turbine, a condenser (using water or air as a coolant) and feed pump. The working fluid in most large fossil fuel powered electrical generating plants is water. For lower temperature levels (such as in certain solar energy applications) the working fluid may be an organic such as one of the freons or toluenes. Current solar energy research efforts in the dynamic generation of electricity involve the use of water with conventional steam turbines. Some effort is being expended in organic fluids for smaller generation units, such as those used in total energy systems. The gas cycles of current interest in solar energy are the Stirling reciprocating engine and the gas turbine. Both of these cycles suffer from the disadvantage that the high temperature source is applied externally with materials limitations dictating the higher temperature limit. This is to be contrasted to the internal combustion versions of both the reciprocating engine and turbine in which the materials operate at temperature below the combustion temperature. Although there are no unique features at Glynco that would require heat engines, several of the larger housing units could be used to test a total energy system.

8. Refrigeration

Current activities in the use of solar energy for refrigeration usually involve the ammonia-water absorption system or standard mechanical compression equipment driven by solar powered heat engines. The lower temperature limit attained by water-lithium-bromide absorption systems eliminates it from contention. The ammonia-water absorption system at present requires some sort of concentrating system to provide the temperature needed in the regenerator. In considering mechanical compression systems driven by solar heat engines it should be kept in mind that the standard procedure is to use a coefficient of performance based on the work input; whereas, for comparison purposes, particularly for solar energy applications it should be based on the solar energy received.

9. Generation of Electricity

The generation of electricity with solar energy may be accomplished by thermoelectric, thermoionic, photovoltaic, and dynamic conversion. Current efforts for the generation of large amounts of electricity are directed towards the dynamic conversion (the use of a heat engine to drive conventional electrical generating units). Of secondary interest is photovoltaic conversion. Photovoltaic conversion is the conversion of incident sunlight on so-called solar cells to a flow of direct current electricity. Silicon and cadmium sulfide are typical materials used in manufacturing solar cells.

10. Energy Storage

Since solar energy is received intermittently, some form of storage is necessary for continuous operation. The various types of energy storage include, dynamic (such as a flywheel), physical changes (such as heat of fusion or temperature changes), and chemical changes (such as an electrical storage battery). It is usual to include wind power and ocean thermal differences as part of solar energy. These are special cases and only indirectly related to what is customarily understood to be solar energy.

11. Miscellaneous Solar Energy Application

Various other types of solar energy applications have been studied. Bioconversion, electrolysis, growth of algae, greenhouses, cooking, and photochemistry are examples. These are important areas and studies relating to them could be easily instituted at Glynco, but none are believed to offer unique implementation at Glynco. Biomass operations, in the nature of growing pulpwood, is already present at Glynco.

IV. ENGINEERING ASSESSMENT

A. Insolation and Climate

1. Direct and Diffuse Solar Insolation

The total daily insolation for the Brunswick, Georgia, area has not been reported by the United States Department of Commerce. However, long term averages are available for Charleston, South Carolina, and for Gainesville, Florida; and these values were used to arrive at estimated insolation for Brunswick. The insolation data as reported was the total solar energy incident on a horizontal surface per unit area for the entire day. The unit normally reported was the langley which is equivalent to 3.687 Btu (British thermal units) per square foot. The data for Charleston and Gainesville are presented in Table II 2/. The values given were average values over at least eight years. As shown, the values for Charleston and Gainesville were approximately the same so that no attempt was made to develop an interpolation procedure to obtain the insolation for Brunswick; and the arithmetic average indicated was used in later calculations. The total insolation is made up of a direct and a diffuse component. The direct component is solar energy that comes directly from the sun. The diffuse component comes indirectly from the sun by scattering in the atmosphere or by reflections from terresterial objects. Flat plate solar collectors can operate on both direct and diffuse radiation. However, curved mirrors or lenses can only utilize the direct component. Thus it is essential in some applications to determine values for both components. In addition, the collector is usually not horizontal so that the effect of collector orientation on the insolation received must be determined. The percentage direct radiation is also a function of angular orientation. The insolation

TABLE II

TOTAL INSOLATION ON A HORIZONTAL SURFACE*

Month	Charleston, S. C. (Btu/ft^2/day)	Gainesville, Florida (Btu/ft^2/day)	Coastal Georgia (Btu/ft^2/day)
Jan.	929	984	957
Feb.	1160	1260	1210
Mar.	1430	1570	1500
Apr.	1890	1910	1900
May	2030	2130	2080
Jun.	2080	1920	2000
Jul.	1920	1800	1860
Aug.	1850	1780	1815
Sep.	1490	1540	1515
Oct.	1250	1280	1265
Nov.	1050	1110	1080
Dec.	830	860	845

*Data obtained from Palm 2/ based on U. S. Department of Commerce Climatological Data National Summary through 1962.

data presented were the total solar energy (both direct and diffuse) incident on a horizontal surface for a day. Solar collectors were usually oriented so that more effective use would be made of their area. In order to base calculations on this type of consideration, the effect of angular position of the collector on both direct and diffuse radiation was calculated from the original insolation data using the method of Liu and Jordan as presented by Duffie and Beckman 3/. The results are presented in Table III. The angles indicated are collector angles with the horizontal for south facing collectors. Integer values of 10, 30, and 55 degrees were calculated as indicated. These are also the approximate values for the angular inclination of flat plate collectors normal to the sun's rays at noon in June, September, and January in Coastal Georgia.

TABLE III

MEAN DAILY INSOLATION FOR COASTAL GEORGIA

Month	$\theta^{*} = 0^{0}$		$\theta = 10^{0}$		$\theta = 30^{0}$		$\theta = 55^{0}$	
Jan.	957**	67***	1085	71	1278	75	1385	78
Feb.	1210	67	1338	71	1496	74	1496	76
Mar.	1500	68	1603	70	1696	72	1590	72
Apr.	1900	73	1975	74	1983	75	1735	72
May	2080	71	2112	71	2033	70	1677	66
Jun.	2000	66	2011	66	1899	65	1531	60
Jul.	1860	63	1876	73	1785	63	1439	56
Aug.	1815	68	1862	68	1829	68	1562	65
Sep.	1515	67	1596	68	1648	70	1502	69
Oct.	1265	67	1378	69	1506	72	1469	74
Nov.	1080	69	1224	72	1424	77	1476	79
Dec.	845	64	969	69	1148	74	1216	77

*θ is the angle of inclination with the horizontal (for a south-facing collector).

**Total Daily, insolation, Btu's/ft^2/day.

***Percent direct radiation.

The total mean daily insolation at various locations in the continental United States are shown in Table IV and Figure 3.

2. Cloud Cover

The cloud cover (represents the percent of the sky obscured by clouds) was of no direct use at present in solar energy applications, but gave some indication of possible rapid changing insolation throughout the day. Again, no data was available for Brunswick, Georgia, but values were reported for Savannah, Georgia, and Jacksonville, Florida. The reported values ranged from a low of 43 percent during October and November for Savannah to a high of 59 percent for June in Jacksonville. The annual average for Savannah was 50 percent; and the annual average for Jacksonville was 52 percent 4/.

3. Climate of the Region

For the purposes of the present study, the climate of Coastal Georgia was adequately described by the monthly average temperature range and monthly average range of relative humidity as well as monthly heating and cooling degree days. Again data was not available from the Department of Commerce for the Brunswick area. However, data was available for Savannah, Georgia, and Jacksonville, Florida. The data for temperature and relative humidity are presented in Table V. Heating and cooling degree day information are needed for comfort heating and cooling calculations. These data are summarized in Table VI. In this table the results for Coastal Georgia are arithmetic averages of the values given for Jacksonville and Savannah. Total annual heating and cooling degree days for several locations are given in Table VII.

TABLE IV

TOTAL MEAN DAILY INSOLATION FOR VARIOUS CITIES IN THE UNITED STATES 2/

Month	Total Mean Daily Insolation (Btu's/ft^2/day)				
	Albuquerque, New Mexico	Coastal Georgia	Boulder, Colorado	Washington, D. C.	Boston, Massachusetts
Jan.	1117	957	741	642	476
Feb.	1423	1210	988	981	715
Mar.	1884	1500	1478	1268	1069
Apr.	2279	1900	1696	1515	1290
May	2529	2080	1696	2032	1641
Jun.	2677	2000	1936	1821	1781
Jul.	2518	1860	1917	1976	1892
Aug.	2308	1815	1619	1644	1515
Sep.	2043	1515	1519	1383	1231
Oct.	1615	1265	1143	1102	866
Nov.	1231	1080	819	778	501
Dec.	1018	845	671	612	424

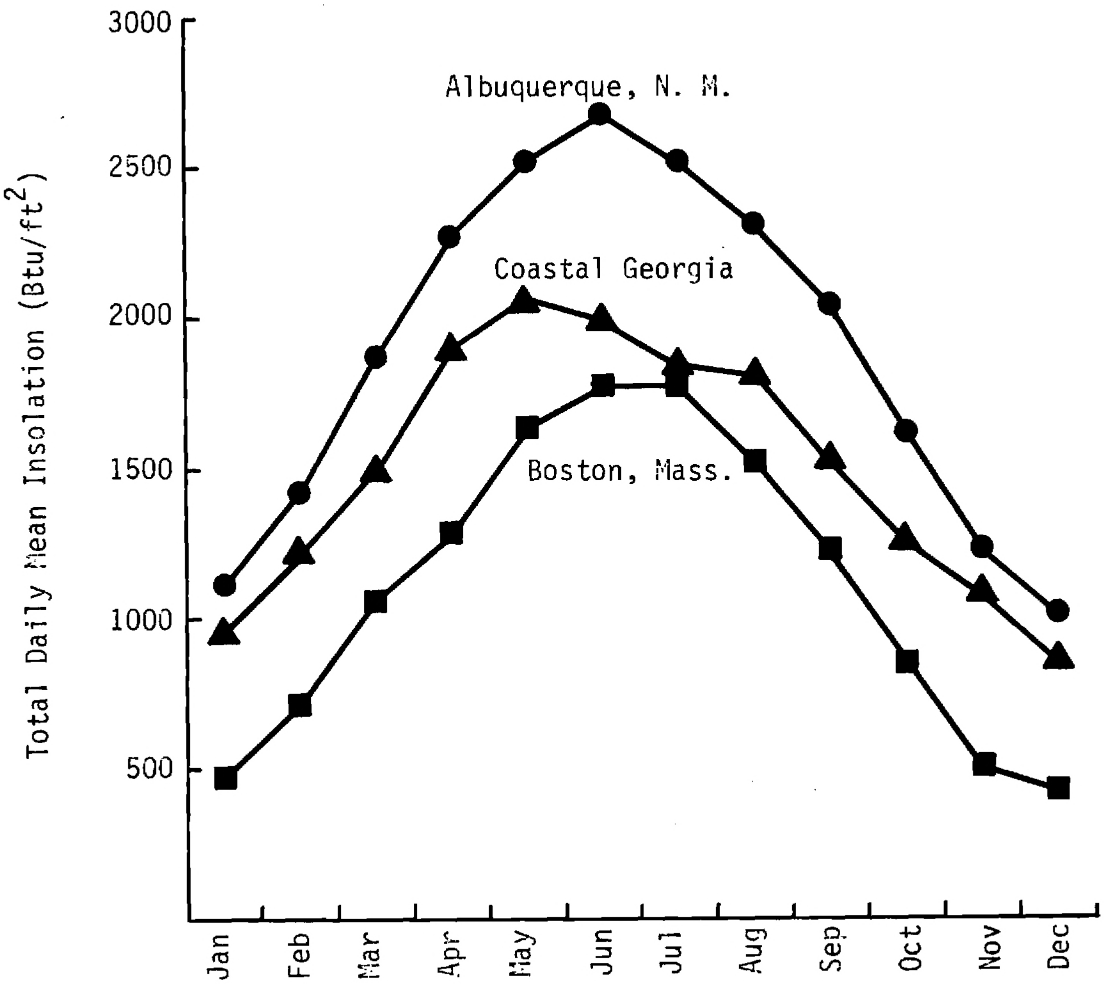

Figure 3. The Total Mean Daily Insolation for Selected Locations in the Continental United States.

TABLE V

MONTHLY MEAN RANGE OF TEMPERATURE AND RELATIVE HUMIDITY*

	Temperature ($^{\circ}$F)			Relative Humidity		
Month	Jacksonville	Savannah	Coastal Georgia	Jacksonville	Savannah	Coastal Georgia
Jan.	45-65	39-61	39-65	57-87	55-84	55-87
Feb.	46-67	41-64	41-67	52-85	50-81	50-85
Mar.	50-72	46-70	46-72	49-85	47-83	57-85
Apr.	57-79	54-78	54-79	47-85	47-85	47-85
May	64-85	62-85	62-85	49-84	51-83	49-85
Jun.	70-88	69-89	69-89	56-86	57-88	56-88
Jul.	72-90	71-91	71-91	58-88	59-89	58-89
Aug.	72-90	71-90	60-90	60-91	63-91	60-91
Sep.	70-86	67-85	67-86	61-91	60-91	60-91
Oct.	62-79	56-78	56-79	58-90	54-88	54-90
Nov.	51-71	45-69	45-71	55-88	49-86	49-88
Dec.	45-66	39-50	39-66	58-88	54-85	54-88

*Based on United States Department of Commerce, Local Climatological Data, average values, 1941-1970 4/.

TABLE VI

HEATING AND COOLING DEGREE DAYS* (BASE 65° F)

Month	Heating Degree Days**			Cooling Degree Days***		
	Jacksonville	Savannah	Coastal Georgia	Jacksonville	Savannah	Coastal Georgia
Jan.	348	483	416	23	0	12
Feb.	282	379	331	0	0	0
Mar.	176	256	216	105	63	84
Apr.	24	63	49	73	63	68
May	0	0	0	279	275	277
Jun.	0	0	0	451	434	443
Jul.	0	0	0	533	540	537
Aug.	0	0	0	488	473	481
Sep.	0	0	0	434	429	432
Oct.	19	60	40	221	177	199
Nov.	161	253	207	80	52	66
Dec.	317	458	388	18	13	16
Totals	1327	1952	1647	2705	2519	2615

*By definition, heating degree days are determined by subtracting the average daily temperature from 65° F, and summing for all days with average temperatures below 65° F. Cooling degree days are determined in a similar fashion by subtracting 65° F from the average daily temperature.

**Average for 1941-1974 4/.

***Based on 1973 4/.

TABLE VII

TOTAL HEATING AND COOLING DEGREE DAYS (BASE 65^{o} F)

	Total Annual Heating Degree Days	Total Annual Cooling Degree Days
Albuquerque	4292	1270
Boston	5621	904
Coastal Georgia	1647	2615
Washington, D. C.	4211	1706

Although Albuquerque is considered to be one of the better locations in the country insofar as insolation is concerned, other factors presented a more favorable picture of the Georgia Coastal area. The sun bowl had twice as many mean annual degree days of cold weather. Large variations in temperature present serious design problems for collectors, heliostats, and other associated solar energy mechanical apparatus. The coastal area of Georgia has an insolation more representative of a large portion of the continental United States. Also, this insolation is more indicative of the potential requirements for conversion to solar energy to meet the future demands of the more densely populated areas of the nation.

B. Types of Structures and Facilities

1. Survey

A study was made of the available structures at Glynco Naval Air Station, Brunswick, Georgia, based on a report supplied by Coastal Area Planning and Development Commission 5/. A cursory list of structures which could readily be utilized in solar energy programs was prepared, and a description of these structures was taken from the above report (see the APPENDIX). Factors which governed the structure selection were (1) reported condition, (2) past use, (3) future use, (4) ease of conversion to solar energy usage, and (5) availability (that is, solar energy studies would not interfere with the prime function of the structure). Prime consideration was given to residential buildings (houses, duplexes, and barracks). A photographic survey of the selected structures was made by a Georgia Tech scientist. He obtained the following information about the status of the structures during his visit to Glynco.

a. A national law enforcement academy would potentially occupy a large portion of the facility. The new classroom building (218/A-8) would then not be available nor would the large asphalt area which surrounds it.

b. Areas south of the airfield had already been put into commercial use.

c. No large land areas were available in the southern section of the base because of the concentration of permanent buildings.

d. A large land area was available north and directly east and west of the present airfield.

Each structure was surveyed for its ease of adaptability to solar energy usage. The structures selected for a solar energy experimental program are shown in Figure 4 and listed in Table VIII. Photographs of the structures are shown in Figures 5 through 16.

TABLE VIII

STRUCTURE SELECTION FOR SOLAR ENERGY EXPERIMENTS

Type of Structure	Descriptive Code		Experimental Priority[1]	Estimated Case of Conversion
	Area	Number		
House	B-1	300-312	1	Variable[2]
House	B-1	313-317	1	Variable[2]
House	B-1	535-700	1	Variable[2]
Duplex	B-2	500-534	1	Variable[2]
Barracks	A-5	63-70	1	1
Warehouse	D-4	28	2	2
Admin. Bldg.	A-6	13	2	3
Golf Clubhouse	C-1	20	2	3
Classroom Bldg	E-1	105	2	1
Laundry	A-5	256	3	1
Gymnasium	C-3	254	3	1
WAVE-Barracks	A-5	71	2	1

1. 1 - High
   2 - Medium
   3 - Low
2. Dependent on site location (typical of building).

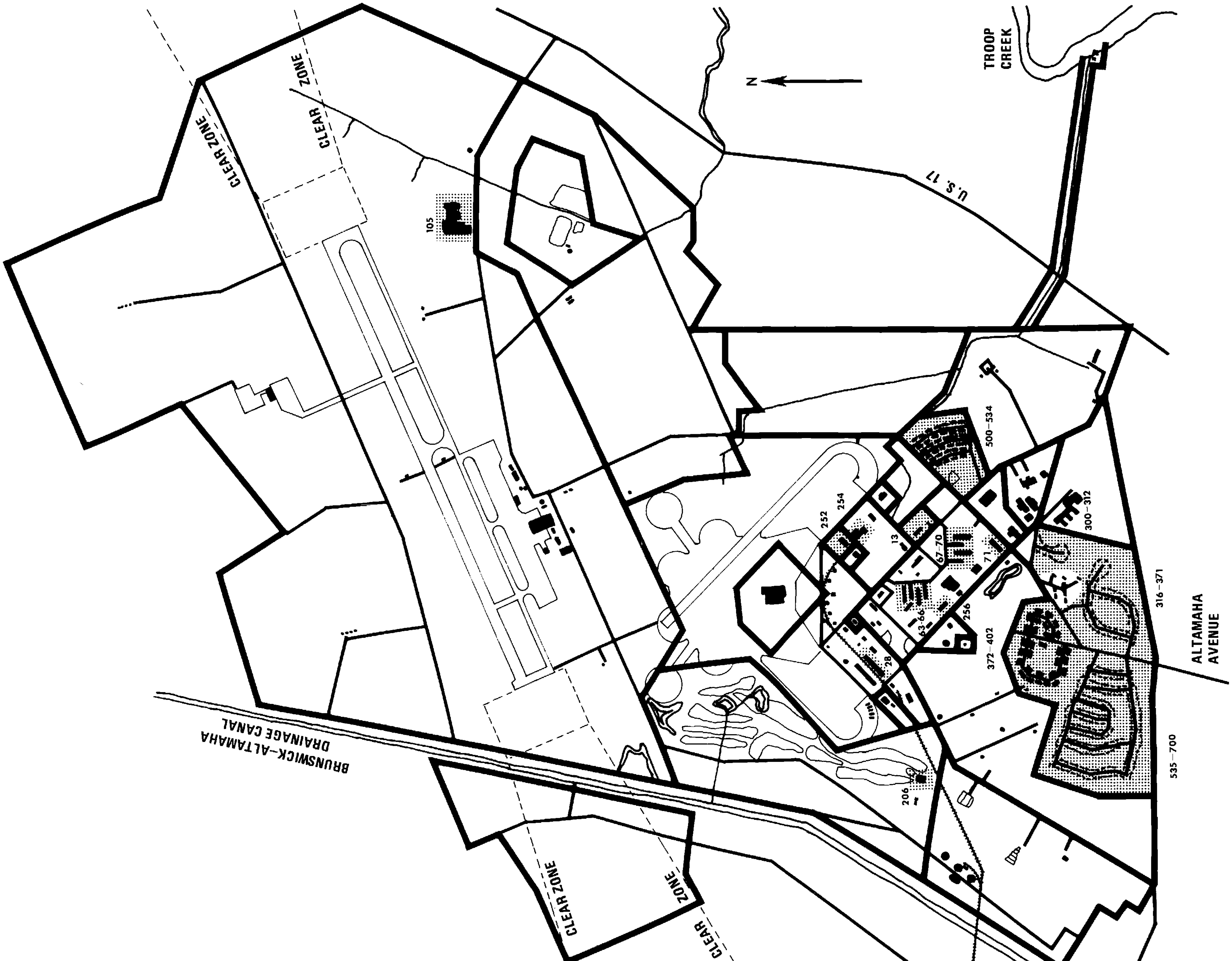

Figure 4. Locations of Selected Structures at Glynco Naval Air Station.

Figure 5. One-Story, Brick House Typical of Design in Area B-1.

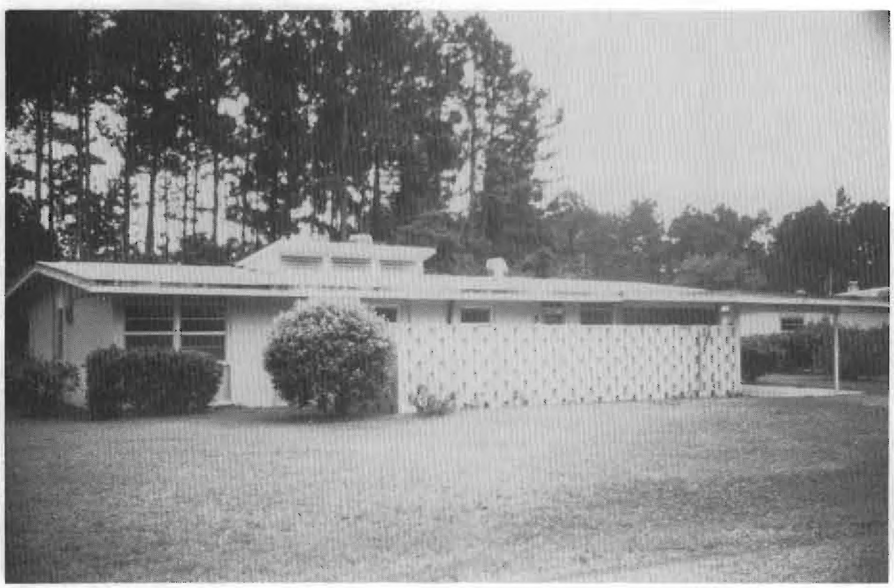

Figure 6. One-Story, Concrete-Block House Typical of Design in Area B-1.

Figure 7. Two-Story, Frame Townhouse Typical of Design in Area B-1.

Figure 8. Three-Story, Concrete Enlisted Men Barracks Typical of Design in Area A-5.

Figure 9. Administration Building, 13, Located in Area A-3.

Figure 10. Rear View of Administration Building.

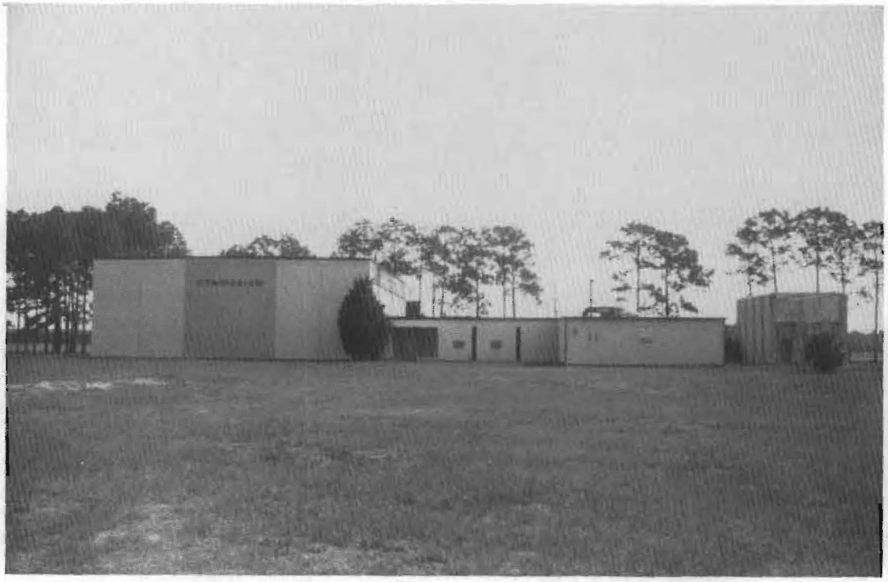

Figure 11. Gymnasium, 254, Located in Area C-3.

Figure 12. Golf Clubhouse, 206, Located in Area C-1.

Figure 13. General Warehouse, 28, Located in Area D-4.

Figure 14. Convenience Shops with Laundry, 256, Located in Area A-5.

Figure 15. Old Classroom Building, 105, Located in Area E-1.

Figure 16. Extended Portion of the West Side of the Old Classroom Building.

2. Utilities

Heat furnished to the structures at Glynco was from one of these forms of energy: (1) electrical, (2) natural fuel gas, (3) oil, (4) steam, and (5) hot water. Family residences were either heated by electricity, natural fuel gas, or oil. All other structures were heated with steam or hot water. It appears that the Navy policy at Glynco was to pay the utility bills based on total consumption for the entire base; therefore, the energy consumed for heating the structures may not be available. However, utilities cost were identified for the commissary which had been licensed to a commercial vendor. The commissary is presently closed.

C. Recommended Research and Development Programs

1. Engineering Parameters

In order to obtain estimates of collector areas required for various applications, collection efficiency had to be known. For the purpose of the present study, only approximate values typical of the various modes of solar energy collection were used and were based on a general interpretation of various references. The values used are given in Table IX. In using Table IX, it should be pointed out that the efficiency of the solar still and the open pond had different bases. In the case of the solar still the desired end result is the vaporization of water, and the efficiency was based on the vaporization rate; whereas, in the open pond and the covered pond, the desired end result is heated water and their efficiency is based on that. These efficiency values are considered to be representative ones suitable for feasibility estimates. An accurate prediction of collector efficiency must be based on a somewhat detailed study of a particular collection and its

TABLE IX

TYPICAL EFFICIENCY VALUES SELECTED FOR ESTIMATION PURPOSES FOR SOLAR ENERGY COLLECTORS

Type of Collector	Efficiency (%)
Solar Still*	35
Open Pond (salt gradient)*	25
Covered Pond*	50
Flat Plate*	
Water as heat transfer fluid	50
Air as heat transfer fluid	45
Cylindrical**	60
Heliostats - Cavity**	65

*Based on total insolation (direct plus diffuse).

**Based on direct insolation only.

conditions of operation. The state-of-the-art does not always permit precise predictions of the collector efficiency. In Table X are the values selected for use in the comfort cooling and refrigeration calculations. These values are also believed to be reasonable estimates suitable for feasibility estimates.

2. Hot Water

A determination of the collector area required to supply hot water for each of the selected structures was made based on an estimated occupancy

TABLE X

TYPICAL COEFFICIENTS OF PERFORMANCE SELECTED FOR ESTIMATION PURPOSES FOR COMFORT COOLING AND REFRIGERATION

Type of Cooling Device	Coefficient of Performance
Absorption*	0.70
Mechanical*	0.40 to 0.70

*Based on solar energy input to cooling device. The mechanical device is assumed to be driven by a solar-powered heat engine. The C.O.P. for the mechanical device is assumed to be on the same basis.

and a value of 20 gallons of water per day per individual with an 90° F temperature rise using flat plate collectors. Although reports had been found of a 40 gallon value used in estimates, it was decided that the lower value represented a more reasonable estimate. The total collector area for January and June were calculated. The results of these calculations are given in Table XI.

3. Space Heating

In order to determine the required heating load using the available information on the various structures, it was necessary to develop an estimating technique using the floor area of each structure. From the floor area, an estimate was made of the exposed surface area of the building (total area of walls and roof). These values are tabulated in Table XII. Further, the total thermal conductance of the structure had to be determined from the floor area and number of stories. Because this procedure is not believed to be too precise, two values were calculated and indicated as "low" or "high."

TABLE XI

ESTIMATED HOT WATER REQUIREMENTS FOR STRUCTURES
IN THE SOLAR ENERGY EXPERIMENTS

Descriptive Code		Estimated Occupancy	Heating Requirement*	Collector Area	
Area	Number	(persons)	(Btu/day)	55^{o} January (ft^2)	10^{o} June (ft^2)
B-1	300-312	4	59,976	87	60
B-1	313-317	4	59,976	87	60
B-1	535-700	4	59,975	87	60
B-2	500-534	8	119,952	174	120
A-5	63-70	100	1,499,400	2,165	1,491
D-4	28	25	374,850	541	373
A-6	13	50	749,700	1,084	746
C-1	20	10	149,940	217	149
E-1	105	500/10**	749,700	1,086	746
A-5	256	500***	7,497,000	10,856	7,456
C-3	254	50	749,700	1,086	746
A-5	71	100	1,499,400	2,165	1,491

*20 gallons of hot water/day/person; 90^{o} F temperature rise.

**Reduced requirement for function of building.

***Increased requirement for function of building.

TABLE XII

ESTIMATED HEATING AND COLLECTOR AREA REQUIREMENTS DURING JANUARY FOR SELECTED GLYNCO STRUCTURES IN THE SOLAR ENERGY EXPERIMENTS*

Descriptive Code**		Estimated Surface	Heating Requirement		55^0 Collector Area	
Area	Number	Area of Structure (ft^2)	Low (Btu/day)	High (Btu/day)	Low (ft^2)	High (ft^2)
B-1	300-312	3,380	217,716	435,432	315	630
B-1	313-317	3,200	206,122	412,244	298	596
B-1	535-700	3,866	249,020	498,040	360	720
B-2	500-534	5,600	360,713	721,426	521	1,042
A-5	63-70	21,460	2,764,602	5,529,204	3,993	7,985
D-4	28	47,144	3,036,682	6,073,364	4,385	9,770
A-6	13	18,280	1,177,468	2,354,936	1,700	3,400
C-1	20	3,640	234,463	268,926	339	677
E-1	105	104,188	6,711,051	13,422,102	9,691	19,382
A-5	256	10,080	649,282	1,298,564	938	1,815
C-3	254	25,000	3,220,645	6,441,290	4,650	9,302
A-5	71	17,600	2,267,334	4,534,668	3,274	6,548

*The ratio of insolation to heating degree days is about the same for December and January.

**See APPENDIX for detailed description of structures.

Even though these values may not be representative of the present structures, they are reasonable values to be used in making estimates to indicate the feasibility of conducting solar energy experiments. The values reported correspond to an apparent overall heat transfer coefficient of 0.20 and 0.40 Btu's/hr-ft^2°F, for all structures except the barracks. Because of the nature of the barracks, which were constructed from concrete, the corresponding values used were 0.40 and 0.80 Btu's/hr-ft^2°F. The results of these calculations are given in Table XII. Using the results for these heating load requirements the necessary flat plate collector areas for operation during the month of January were made using the heating degree days from Table VI. The collector area requirements are also given in Table XII.

4. Air Conditioning

In a similar manner the required flat plate collector areas for air conditioning was calculated for the month of June using coefficients of performance of 0.40 and 0.70. The results are given in Tables XIII and XIV.

5. Architecture

In estimating cooling loads, solar energy is normally considered to be an important factor in architectural design. Therefore, solar energy as related to architecture in the past has been a consideration. The new emphasis on energy conservation and utilization, however, had resulted in further investigation of this area. The converse factor of supplemental heating by solar energy in the past has usually not been a consideration. The combined architectural utilization of solar energy as a supplement in

TABLE XIII

ESTIMATED AIR-CONDITIONING REQUIREMENTS DURING JUNE* FOR STRUCTURES IN THE SOLAR ENERGY EXPERIMENTS (C.O.P. = 0.40)

Descriptive Code		Estimated Surface Area of Structure	Collector Energy Requirement		10^{0} Collector Area	
Area	Number		Low	High	Low	High
		(ft^2)	(Btu/day)	(Btu/day)	(ft^2)	(ft^2)
B-1	300-312	3,380	598,936	1,197,872	595	1,190
B-1	313-317	3,200	567,040	1,134,080	564	1,127
B-1	535-700	3,866	685,062	1,370,124	681	1.362
B-2	500-534	5,600	992,320	1,984,640	987	1,974
A-5	63-70	21,460	7,605,424	15,210,848	7,564	15,278
D-4	28	47,144	8,353,910	16,707,820	8,309	16,618
A-6	13	18,280	3,239,215	6,478,430	3,222	6,444
C-1	20	3,640	645,008	1,290,016	642	1,285
E-1	105	104,188	18,463,210	36,924,420	18,361	36,722
A-5	256	10,080	1,786,176	3,572,352	1,776	3,552
C-3	254	25,000	8,860,000	17,720,000	8,811	17,623
A-5	71	17,600	6,237,740	12,475,480	6,203	12,407

*June is a typical month for air conditioning. July, August, and September would require about 30 percent more collector area.

**The cooling load can be calculated by multiplying the collector energy requirement by the C.O.P. This could be converted to tons of cooling required (12,000 Btu's/hr = one ton) but would only represent an average value and not the necessary cooling capacity which would be required to handle the peak demand during the day.

TABLE XIV

ESTIMATED AIR-CONDITIONING REQUIREMENTS DURING JUNE* FOR STRUCTURES IN THE SOLAR ENERGY EXPERIMENTS (C.O.P. = 0.70)

Descriptive Code		Estimated Surface	Collector Energy Requirement*		10^{o} Collector Area	
Area	Number	Area of Structure (ft^2)	Low (Btu/day)	High (Btu/day)	Low (ft^2)	High (ft^2)
B-1	300-312	3,380	342,249	684,498	340	681
B-1	313-317	3,200	324,023	648,046	320	545
B-1	535-700	3,866	391,464	782,928	389	779
B-2	500-534	5,600	567,040	1,134,080	564	1,128
A-5	63-70	21,460	4,345,956	8,691,812	4,322	8,644
D-4	28	47,144	4,773,622	9,547,324	4,748	9,495
A-6	13	18,280	1,850,980	3,701,960	1,841	3,682
C-1	20	3,640	368,576	737,152	367	733
E-1	105	104,188	10,549,833	21,099,666	10,492	20,984
A-5	256	10,080	1,020,672	2,041,344	1,015	2,030
C-3	254	25,000	5,062,857	10,125,714	5,035	10,070
A-5	71	17,600	3,564,251	7,128,502	3,545	7,090

*June is a typical month for air conditioning. July, August, and September would require about 30 percent more collector area.

**The cooling load can be calculated by multiplying the collector energy requirement by the C.O.P. This could be converted to tons of cooling required (12,000 Btu's/hr = one ton) but would only represent an average value and not the necessary cooling capacity which would be required to handle the peak demand during the day.

heating and the reduction of cooling losses from solar energy is a more involved problem. However, in some cases, relatively simple schemes such as overhanging eaves on south facing walls which provide some shading during the cooling season, but not during the heating season are worthy of consideration. Although no specific recommendations in this regard are made for Glynco, many of the structures available for use would provide opportunities for the study of architectural modifications which might reduce total energy consumption including both heating and cooling.

6. Total Energy Systems

A total energy system for this program is defined as a system which provides the energy requirements in the appropriate form (thermal and electrical) for a unit, a group of units, or an entire complex. Such a system would consist of a collector solar cell array or a combined collector-dynamic electrical conversion system. Current investigations generally tended to use solar cells and flat-plate air-heaters collector for a single family dwelling or other similar small units. The consideration of larger units, such as an apartment complex or multistory building, involve concentrating collectors and dynamic electric power generation. Alternate energy sources (stand-by) or energy storage would have to be provided.

Although the generation of electricity in either case is performed at relatively low efficiencies, the rejected energy can be used to advantage in heating or air conditioning devices. Thus increase in the collector area requirement should be approximately proportional to the percentage of electrical energy requirements. This was estimated to vary from five to fifteen percent of the heating load requirements. However, two additional considerations need to be evaluated. The first is the use of solar cells in which air heating is the heat transfer medium. The collection efficiency is reduced somewhat for air heating when compared to the values for a flat plate collector using water as the heat transfer fluid. The second is that in the case of large dynamic conversion systems, focusing collectors are usually used. Although focusing collectors normally operated at higher efficiencies than flat plate collectors, they made use of only the direct component of insolation. Also, tracking the sun results in a larger solar input. The end result is that an estimate of the collector area (aperture area for a concentrating collector) required for a total energy system accurate enough for the purpose of the present study can be made by increasing the collector area requirements for heating or cooling by approximately ten percent.

7. Agricultural Applications

One of the agricultural applications considered was that of crop drying. The crops dried in Georgia include corn, small grain, tobacco, peanuts, and soybeans. Considerations in drying operations are related to the specific crop being dried, its moisture contact, and the local weather conditions.

In order to make a preliminary estimate of drying in the Coastal Georgia region, it was assumed that the local conditions were such that the dry bulb temperature was 85^{o} F, and the relative humidity was 60 percent. The drying process was assumed to consist of the air being heated to 140^{o} F in a flat plate collector and then used to dry the crop. The crop being dried was assumed to contain enough moisture so that only the constant-rate portion of drying was involved. Based on insolation in September and a collector efficiency of 45 percent the collector area required to remove one thousand pounds of water was determined to be about 1425 square feet.

Preliminary calculations were also made to determine the effect of increasing the solar energy absorptivity of the soil for increasing the soil temperature as has been suggested by others. These calculations indicated that this would be an advantage during the day and would, as expected, be detrimental at night unless some provision is made to cover crops. This could be of some benefit, but some preliminary experimental work is needed before an accurate evaluation can be made.

Solar stills were considered for the production of fresh water from sea water. Since solar stills will be mentioned later in conjunction with industrial processing, they are not discussed further here.

8. Industrial and Commercial

Hot water heating, space heating, and air conditioning could be used in industrial and commercial applications. In addition, various processes could be adapted to use solar energy.

A frozen food operation could be run using a solar driven refrigeration device. This could be either a mechanical or an absorption refrigerating unit. An estimated collector site for an absorption system is given in Table XV.

There are many elements in sea water that have commercial values. The major elements present in a typical sea water are given in Table I. There are many ways to process sea water in order to obtain the element(s) or compound(s) desired. An age-old method for the production of salt is the complete evaporation in open ponds of all of the water to solar energy.

TABLE XV

COMMERCIAL AND INDUSTRIAL APPLICATIONS

Application	Operating Conditions	Approximate Collector Size
Refrigeration	Cylindrical collector, tracking, North-Side axis, perpendicular to sun's rays at noon in June, C.O.P. = 0.70	330 ft^2/ton of refrigeration (aperture area)
Solar Still	December	0.65 acres/1,000 gallons/day
Open Pond (salt gradient)	December	5.0 ft^2/1,000 Btu's/day
Closed Pond	December	2.5 ft^2/1,000 Btu's/day
Process Steam	Cylindrical collector, North-South axis, perpendicular to sun's rays at noon in December	1800 ft^2/1,000 pounds steam/day (stationary) 1100 ft^2/1,000 pounds steam/day (tracking)
Kiln for Brick Plant*	Heliostat-Cavity in December	2.5 acres/20,000 bricks/day
Thermal Requirements for Kaolin Plant** (hydrocloric acid process)	Heliostat-Cavity in December	1.0 acres/ton of alumina (stationary)

*Based on data in Reference 8.

**Based on data in Reference 9.

More refined chemical processing techniques are needed for a selective production.

One initial step which shows some promise is the use of a solar still to simultaneously provide fresh water and to concentrate the solids about twofold. The concentrated solution can then be used as the feed for a mineral beneficiation plant.

An estimated solar-still size for such a plant is also given in Table XV, based on information in Reference 7.

Process heat refers to the energy requirements in industrial and commercial operations. Such energy can be conveniently categorized (although somewhat arbitrarily) into the following ranges: up to 100° C (the boiling point of water at one atmosphere pressure), 100° C to 176° C (an approximate upper limit for process steam), and above 176° C (low, medium, and high temperature furnace operation).

One method under study by some researchers to provide process hot water is to use an open pond with a salt gradient to provide hot water at about 150° F. The approach is in the research and development stage, but has the advantage of relatively low cost. Of course, flat plate collectors could be used for such an application, but current thinking is that the cost would be greater than that of an open pond. An estimate of the size of pond needed is given in Table XV.

A disadvantage of the open pond is its relatively low efficiency (25 percent). The covered pond, also in the development stage, has a much better efficiency (50 percent) but an increased cost because of the covers used to eliminate evaporation losses. An estimate of the size of covered pond is also given in Table XV.

In order to provide process steam in the range of 100^{0} C to 176^{0} C using the anticipated state-of-the-art in the near future some form of optical concentration will be required. This could be in the form of lenses, curved mirrors, or multiple collectors (heliostats-cavity). Tracking of the sun may or may not be required. Tracking, of course, would increase the cost of the system. Cylindrical collector areas required to generate steam are also given in Table XV.

As mentioned earlier, solar energy could also be used for the operation of furnaces of kilns. To date most of these operations have been highly specialized and of a nature more oriented to research rather than production. However, in principle, any industrial operation presently using fossil fuels can be conducted using solar energy. At the present time, the cost in most cases would probably be prohibitive. An estimate for a kiln operation in a brick plant and for the thermal requirements in a kaolin plant are also given in Table XV.

9. <u>Dynamic Electrical Power Generation</u>

Large scale research efforts are underway today through federally sponsored funds with the end goal of building and operating a ten megawatt solar energy powered electrical generating plant. In order to determine the facility requirements for such a plant, an estimate of the land area required was made. This calculation was based on an assumed solar input rate of 200 Btu's-hr/ft^2 for a surface normal to the sun's rays, a land use factor of 35 percent (land area is mirror area divided by 0.35), and an overall thermal efficiency of 25 percent. This yielded a land area requirement of approximately forty acres. This amount of land is readily available at Glynco.

V. RECOMMENDATIONS

Various estimates have been made of the relative amounts of different types of energy consumption in the United States. Air conditioning and water heating consume a total of about seven percent and space heating about eighteen percent. Process steam alone accounts for about sixteen percent. Thus, any sizable usage of solar energy in these areas will make a considerable impact on the nation's consumption of energy.

Based on the premise that a solar energy research and development laboratory is established at Glynco, the following developmental projects are recommended for immediate implementation:

1. Hot water heating
2. Space heating
3. Air conditioning
4. Total energy systems

These projects should be implemented using the existing structures. In each of these studies architectural modification could well play an important role.

The next set of projects should include:

5. Agricultural drying
6. Refrigeration
7. Process hot water
8. Process steam

Longer term projects should include:

9. Minerals beneficiation from the ocean

10. Kilns and furnaces

11. Electrical power generation

The projects listed above are major ones. There are many additional projects of smaller scope that would naturally be initiated along (for example, a swimming pool heater) with the major ones. Because of the intermediate nature of the insolation and climate at Glynco as compared to the result of the continental United States, the results of these projects could be used almost anywhere in the country. Because of the fact that Glynco was previously a navy base, the result of these studies will also provide information on housing typical of military bases.

APPENDIX

BUILDINGS SELECTED TO SURVEY FOR POSSIBLE USE IN SOLAR ENERGY EXPERIMENTS

Building Number	Location	Description and Comments
6-7	B-1	Two-story, brick; 2500 ft^2; single family; built 1943; good condition; heavily shaded and in woods; steep roofs; difficult to use for experimentation.
13	A-6	Administration building; 14,000 ft^2 built 1943; frame construction; good condition; faces Southwest; poor exposure to south because of trees; pitched roof.
23	A-9	Water treatment facility; 2.44 million gallons per day; wooded land available near location.
28	D-4	General warehouse; 29,000 ft^2; frame construction; built 1943; good condition; electric and gas heat; long axis from southwest; slight pitched roof; good solar exposure.
41	C-3	Boiler house; heat supply for gymnasium.
63-70	A-5	EM barracks; about 22,000 ft^2 each; about 100 men each; concrete construction; 63-65 face north/south; 66-70 face east/west; flat or very slight pitched roofs; good solar exposure.
71	A-5	WAVE barracks; 16,000 ft^2; 100 women; concrete construction unfinished; flat roof; faces southeast; presently in shade.
74	A-5	Boiler house; built 1955; provides central heat for EM barracks and EM mess hall; steam distribution lines require replacement.
75	A-5	EM mess hall; 30,000 ft^2; 1500 men, built 1955; brick construction; requires repair of mechanical equipment and pipe facilities.
76	A-2	BOQ dormitory and dining facilities; 85,000 ft^2; 245 men; built 1955; brick construction; flat roof; wooded land available near location; good solar exposure.

Building Number	Location	Description and Comments
83	C-3	CPO swimming pool; 60 ft x 25 ft x 8 ft; built 1952; considered best pool; shaded; open land available near location.
93	A-11	CPO club; 7,000 ft^2; built 1972; brick construction; flat roof; central kitchen facility; good condition, good solar exposure.
94	A-3	Dispensary/Dental Clinic; 32,000 ft^2; concrete construction; unfinished; flat roof; good solar exposure.
95-86	A-7	BOQ Dormitories; 31,000 ft^2 each; 100 men each; concrete construction; flat roof; unfinished; good solar exposure.
97	A-7	Officers mess; 9,500 ft^2 construction no started.
104	E-1	Crash truck/Boiler house; 2,465 ft^2; built 1955; brick construction; good condition; part of air operation; large open area available; very good solar exposure.
105	E-1	Classroom building; 155,000 ft^2; 377 men, built 1955; brick construction; good condition; complex of buildings; very large open area available; very good solar exposure.
201	A-4	Boiler house; 560 ft^2; 2 million Btu/hour; built 1958; poor location near railroad tracks.
206	C-1	Golf clubhouse; 1,900 ft^2; frame construction; four separate pitched roofs; good condition; shaded; area can be cleared easily.
210	A-8	Classroom building; 92,000 ft^2; 473 men; brick construction; flat roof; built 1970; good construction; very good solar exposure; adjacent asphalt apron.
250	A-11	Hobby shop; 4,200 ft^2; brick construction; flat roof; built 1973; very good condition; good solar exposure.
252	C-4	Bowling alley; 12 lanes; brick construction; flat roof; built 1971; good condition; good solar exposure.

Building Number	Location	Description and Comments
254	C-3	Gymnasium; 15,000 ft^2, brick construction, flat roof; built 1964; good condition, very good solar exposure.
256	A-5	Laundry/Express store; 5,520 ft^2; brick construction; flat roof; built 1962; fair condition; good solar exposure; part convenience store complex; little open area available.
257	A-7	Officers' swimming pool; 82 ft x 75 ft x 12 ft; built 1962; shaded.
266	A-5	EM swimming pool; built 1959; good condition; shaded; little area available.
300-312	B-1	House; single family; 1,600 ft^2; one-story, concrete block construction; slight pitched roof; built 1957; good solar exposure.
313-371	B-1	House; single family; 1,500 ft^2; one-story brick construction; pitched roof; built 1961; variable solar exposure dependent on location and position.
372-402	B-1	Townhouse; four family; two-story frame construction; pitched roof; built 1973; variable solar exposure dependent on location and position.
500-534	B-2	Duplex; two family; 3,000 ft^2; one-story; brick construction; flat roof; built 1957; good solar exposure.
535-700	B-1	House; single family; 2,000 ft^2; one-story brick construction; pitched roof; built 1961; variable solar exposure dependent on location and position.

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